Physics 226: Problem Set #7
Due in Class on Thursday Oct 27, 2016

1. Draw a Feynman diagram involving a W boson for each of the following processes:

   (a) $\tau^+ \to e^+ + \nu_e + \bar{\nu}_\tau$

   (b) $K^0 \to \pi^- + e^+ + \nu_e$

   (c) $D^+ \to \overline{K^0} + \mu^+ + \nu_\mu$

   (d) $\tau^+ \to \bar{\nu}_\tau + \pi^+$

   (e) $\Lambda \to p + e^- + \bar{\nu}_e$

   (f) $\nu_e + e^- \to \nu_e + e^-$

2. For each of the weak interations listed below replace the unknown X with the appropriate particle:

   (a) $\pi^+ \to \pi^0 + e^+ + X$

   (b) $X \to e^+ \nu_e \bar{\nu}_\mu$

   (c) $K^+ \to X e^+ \nu_e$

   (d) $X + p \to n + e^+$

   (e) $D^0 \to K^- + \pi^0 + \nu_e + X$

3. Estimate the relative rates for the following four decay modes of the $D^0 (c\bar{u})$ meson: $D^0 \to K^- \pi^+$, $D^0 \to \pi^- \pi^+$, $D^0 \to K^+ \pi^-$, $D^0 \to \pi^0 \pi^0$. Express these as the branching ratio of each decay mode divided by the branching ratio for $D^0 \to K^- \pi^+$. As part of your answer, draw Feynman diagrams involving W bosons for each decay. How well do your estimates agree with the experimental ratios?

4. Consider the rare leptonic decay $B^+ \to \ell^+ \nu_\ell$.

   (a) Explain in words, with an accompanying diagram, why this decay is rare.

(b) We saw in class that the charged pion has a partial width for its decay to a muon

$$\Gamma(\pi^+ \rightarrow \mu^+ \nu) = \frac{G^2}{8\pi} f_\pi^2 m_\pi m_\mu^2 \left(1 - \frac{m_\mu^2}{m_\pi^2}\right)$$

where f_π is a constant that is related to the π wave function at the origin, has units of mass and has a value approximately equal to m_π. Using the analog of this expression, calculate the relative rates for the B^+ to decay to the 3 lepton species e, μ and τ.

(c) From the particle data group web page, state whether this decay has been observed for the cases of $\ell = e$, μ and τ and if the decay has been observed, give the observed branching ratio and its uncertainy.

(d) Use the results above to estimate f_{B^+}. Warning: make sure you include the effect of the CKM matrix in the estimate.

(e) Repeat (a), (b) and (c) for the D_s.

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